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PRE-PRODUCTION ENGINEERING AND CERTIFICATION OF FIOVALVE BACKWATER VALVE

Alberta
MUNICIPAL AFFAIRS
Innovative Housing Grants Program

[redacted]

PRE-PRODUCTION ENGINEERING AND CERTIFICATION OF FIOVALVE BACKWATER VALVE

August 1987

Prepared by:

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Consulting Engineers Inc.

For:

Fiodrain Ltd.

The views and conclusions expressed and the recommendations made in this report are entirely those of the authors and should not be construed as expressing the opinions of Alberta Municipal Affairs.

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FOREWORD

The project documented in this report received funding under the Innovative Housing Grants Program of Alberta Municipal Affairs. The Innovative Housing Grants Program is intended to encourage and assist housing research and development which will reduce housing costs, improve the quality and performance of dwelling units and subdivisions, or increase the long term viability and competitiveness of Alberta's housing industry.

The Program offers assistance to builders, developers, consulting firms, professionals, industry groups, building products manufacturers, municipal governments, educational institutions, non-profit groups and individuals. At this time, priority areas for investigation include building design, construction technology, energy conservation, site and subdivision design, site servicing technology, residential building product development or improvement and information technology.

As the type of project and level of resources vary from applicant to applicant, the resulting documents are also varied. Comments and suggestions on this report are welcome. Please send comments or requests for further information to:

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Subsequent to the completion of this report, the manufacturing and marketing rights for the Fiovalve Backwater Valve have been purchased by:

Better Marketing Ideas (BMI) Ltd.
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EXECUTIVE SUMMARY

INTRODUCTION

The Fiovalve is a patented backwater valve used to prevent sewer backflow into residences and commercial buildings. It functions in the open position under normal operating conditions which does not restrict air flow and, therefore, allows its installation in the main waste line. It has operated very successfully in field installations and has received favorable response from provincial plumbing regulatory authorities. While meeting all CSA performance requirements, the original pre-production body castings had minor dimensional inaccuracies which precluded CSA certification and therefore limited its marketability.

APPROACH

An extensive pre-production engineering investigation which would satisfy CSA certification requirements was conducted under the assistance of the Innovative Housing Grants Program (IHGP) in four phases. These were 1) problem definition, 2) implementation of solutions, 3) CSA certification, and 4) final documentation.

FINDINGS AND SOLUTIONS

A review confirmed that the functional operation of the Fiovalve was entirely satisfactory to CSA and met its specifications. The review also concluded that the dimensional inaccuracies, namely, spigot diameters and out-of-roundness that exceeded very narrow tolerance limits, were due to small mold dimension errors and the effects of residual stresses developed during cooling of the injection molded body casting.

Correction took two paths. First, minor mold modifications were effected and, second, suitable injection parameters to minimize distortion were established through extensive empirical trials. The latter were based on scientific knowledge of materials properties and the effects of injection process parameters.

Engineering purchasing specifications and quality assurance procedures were established from the results of the investigation and were implemented by Fiodrain

Ltd.. Samples from the first production run were submitted to CSA along with Fiodrain's quality assurance manual. CSA certification of the product was subsequently granted.

CONCLUSION

Fiodrain Ltd., as a result of the IHGP project, has established excellent in-house and vendor quality assurance programs thus enabling cost-effective production of reliable and consistent products with continuing CSA compliance. Fiodrain Ltd. is therefore in a stronger position to market the Fiovalve and also to gain certification in the American market. Areas of product cost reductions and enhancements have been identified which can be introduced as economics permit or the marketplace requires.

The objectives of the project have been met. In conclusion, the assistance provided by IHGP was both timely and vital in assisting this well designed, innovative product to meet regulatory requirements and thereby gain wider market acceptance.

1.0 INTRODUCTION

1.1 General

The Fiovalve is a backwater control device used to prevent sewer backflow into residences and commercial buildings. A major difference and advantage over conventional check flow devices is that the Fiovalve is open in its normal position. Thus it does not restrict air flow nor is it prone to clogging with waste materials. Non-restriction of air flow permits installation in the main drain line allowing one Fiovalve to protect a residence with several secondary waste lines. The Fiovalve, which generally matches main drains for residences, has 4 inch inlet and outlet diameters. Connections may employ solvent welding or mechanical clamps (M-J clamps). M-J clamps are most often employed in retro-fit installations and also allow connection to waste lines made of different materials like cast iron.

The Fiovalve has been laboratory and field tested extensively and received very favorable response from several provincial plumbing regulatory authorities and municipal sewage departments. Several municipalities, including Edmonton, have established grants or tax credits to assist homeowners to install a Fiovalve. This is because the Fiovalve's reliable operation greatly reduces the risk of sewer backup damage compared to present back flow devices. Installation of Fiovalves in older areas where sewage systems are overloaded is particularly advantageous to both the home owner and the municipality. Widespread Fiovalve installations could lead to a better utilization of sub-grade space in residential and light commercial buildings while reducing or maintaining existing insurance premiums.

In order to achieve these benefits, the Fiovalve requires certification by the Canadian Standards Association (CSA), which is recognized by all Canadian plumbing regulatory jurisdictions.

1.2 Fiovalve Operation

The Fiovalve is a normally open backflow control device that prevents sewer backup damage. Since venting of sewer gas is unimpeded, the Fiovalve may be placed in the main waste line protecting the entire plumbing system. Figure 1 shows a typical installation.

FIG. 1

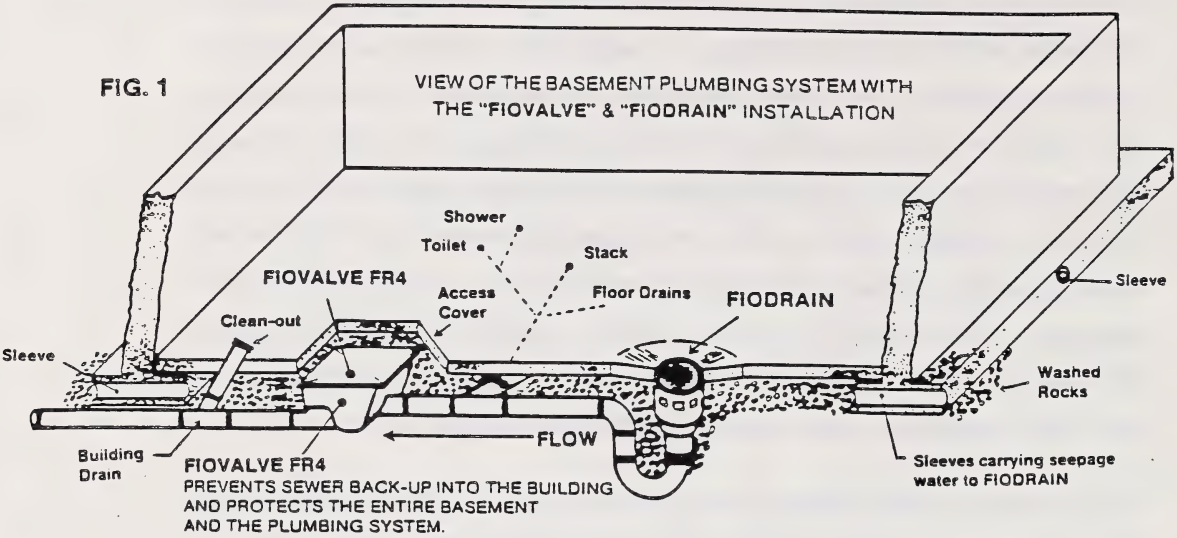
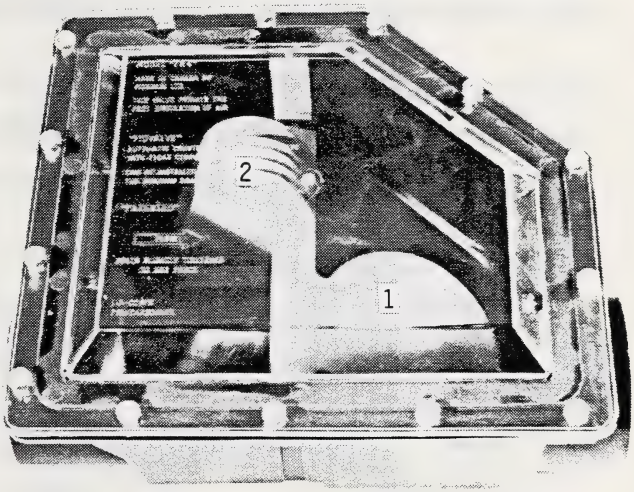

VIEW OF THE BASEMENT PLUMBING SYSTEM WITH THE "FIOVALVE" & "FIODRAIN" INSTALLATION
Shower
Toilet
Stack
FIOVALVE FR4
Access Cover
Floor Drains
FIODRAIN
Sleeve
Clean-out
Sleeve
Washed Rocks
FLOW
Building Drain
FIOVALVE FR4
PREVENTS SEWER BACK-UP INTO THE BUILDING AND PROTECTS THE ENTIRE BASEMENT AND THE PLUMBING SYSTEM.
Sleeves carrying seepage water to FIODRAIN

Figure 1: Typical installation of Fiovalve in a residence showing how one Fiovalve can protect the entire waste and vent system.

Operation of the Fiovalve is simple and effective. The reader may refer to Figures 2 through 4 and to the appendix. The Fiovalve body is a rugged ABS injection molding that contains inlet and outlet spigots with a valve seat on the inlet's downstream face inside the valve body. The spigots connect to the drain waste line. A gate closure with an elastomeric gasket is held in the normally open position by counterweights on the gate closure axle. The valve body interior has two compartments with the first allowing free flow of normal waste water through the valve. A second compartment located below the counterweights and connected to the main compartment acts as a float chamber. Any backflow into the Fiovalve enters the float chamber and causes the float to rise against the counterweights. This, by design, exerts a moment on the gate closure causing it to begin to close. If the rise in water level is sufficient, the gate closure contacts the inlet seat and does not permit further fluid passage. The float buoyancy and counterweight geometry are designed so that water levels from normal drain action do not activate the valve. During sewer backups, considerable pressure is created which acts against the closure gate creating an effective seal by increased gasket compression.

Figure 2:

Assembled Fiovalve shown in the normal or open position. The gate closure (1) is held open by the counterweight (2) allowing passage of waste water from left to right while allowing unimpeded venting of sewer gases. Use of a clear polycarbonate lid permits simple visual confirmation of the closure's position and the condition of the valve.



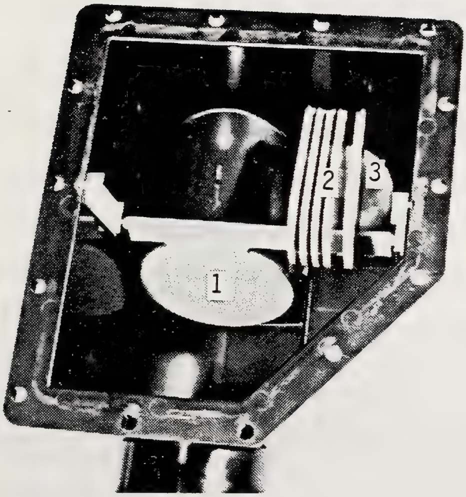


Figure 3:

The polycarbonate lid has been removed and the gate closure is shown in the closed position. In practice, rising water levels during backflow forces the float (3) against the counterweight (2) closing the gate closure (1). Pressure of the rising water exerted against the closure effects a seal of the elastomeric gasket.

An optional alarm system detects closure of the Fiovalve thus alerting the homeowner to a back flow condition. In addition to preventing an inadvertent flood through use of drains or toilets when the valve is closed, the homeowner can take whatever precautionary actions the factors causing the backflow warrant.

The alarm consists of a battery operated buzzer activated by a magnet on the gate closure axle which closes a magnetic reed switch as the valve gate closes.

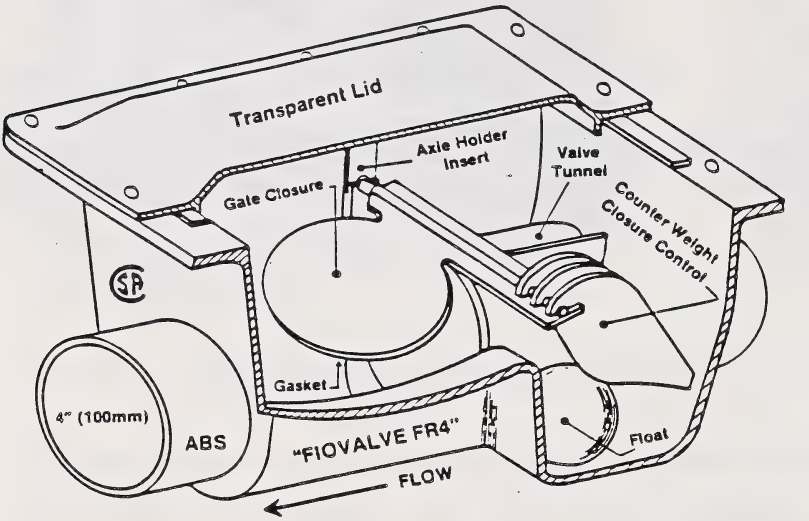


Figure 4: Cut-away drawing showing the Fiovalve components.

1.3 Objectives of the Project

The design of the Fiovalve is quite simple and its operation is reliable. However, to function as designed, the main body injection molding is necessarily complex and is subject to dimensional instabilities due to shrinkage and thermal stresses. The CSA standard that applies to the Fiovalve specifies very narrow dimensional tolerances to ensure compatibility between plumbing fittings and devices from all certified manufacturers. To obtain CSA certification, it was necessary to resolve certain dimensional problems and develop quality assurance procedures. Because Fiodrain Ltd., the Fiovalve manufacturer, has limited in-house engineering resources, it was necessary to hire outside expertise to solve the problem. Anderson Associates Consulting Engineers Inc. were subsequently retained.

The objective of this project was to determine and correct current and anticipated problems related to the design, certification and production of the Fiovalve. The detailed objectives were:

- to determine and correct the problems which appear to occur during the molding process and which result in a non-standard product;
- to review the Fiovalve design and production process and correct any other problems which may exist;
- to obtain CSA Certification for the Fiovalve under CAN3-B181.1-M85 “ABS Drain, Waste, and Vent Pipe and Pipe Fittings”; and
- to develop and document quality control procedures which will help to ensure the production of a consistent and acceptable product with continued CSA certification.

1.4 History of CSA Certification of the Fiovalve

Difficulties between Fiodrain Ltd. and CSA over certification were not related to the Fiovalve’s operation but rather to dimensional tolerances and the establishment manufacturing and quality assurance procedures required to maintain CSA’s strict, but proper, engineering specifications. Operationally, the Fiovalve was entirely satisfactory.

At the time Anderson Associates Consulting Engineers Inc. was retained, the CSA certification process was essentially stalled because of problems related to the diameters of inlet and outlet spigots. Unfortunately, the original Italian moldmakers had not been provided with CSA specifications for the spigot diameters which were instead estimated from a sample of 4 inch diameter ABS drain pipe. As a precaution, the spigot outside diameter was left undersize to allow correction in

Canada by machining. Had the spigot diameter been oversized originally, very expensive mold modifications would have been necessitated to reduce the product diameter to specification. This may have required replacement of the main die block.

Fiovalve samples injected from the original mold were provided to CSA for testing and were satisfactory except for spigot diameters. The molds were then enlarged by electrical discharge machining (EDM) in Edmonton. Several hundreds of bodies were injected and many were installed as retrofit to existing waste lines. Retrofitting employs M-J clamps, therefore the spigot dimensional tolerances are less demanding than for solvent welding of socket and spigot fittings. However, the spigots remained undersize and CSA once again withheld their certification.

At this point, the Certification process had taken about two years and Fiodrain Ltd. were actively promoting the Fiovalve. Some limited installations were occurring and the Fiovalve was functioning very well in service. These were installed with the approval of local plumbing regulatory authorities and CSA certification was not required. However, the CSA monogram had been applied and CSA's position on the unauthorized use of their symbol was hardening with legal action a definite possibility. Anderson Associates Consulting Engineers Inc. personnel met with the Toronto-based CSA plumbing certification personnel in Edmonton in January 1987. CSA presented their position which made it clear that Fiodrain must correct all deficiencies and meet all dimensional tolerances specified, not withstanding Fiodrain's reluctance to further mold modifications. (Current replacement costs of the molds are in the order of $300,000.)

A preliminary assessment indicated the dimensional problem was related to the body geometry, injection parameters and thermal history as well as the original mold dimensions. Hence, Fiodrain Ltd. applied under the Innovative Housing Grants Program for financial assistance to investigate and correct the problem in order to gain CSA certification.

2.0 REGULATORY CONSIDERATIONS

2.1 Canadian Standards Association

2.1.1 General

Canadian Standards Association is a private standards writing, testing and certification organization which currently publishes over 1,000 standards. Representation on Standards Committees includes all levels of government, professional and research organizations, manufacturers, trade organizations, labour unions and consumer groups.

Compliance with many of the CSA Standards has been made mandatory by their inclusion into federal and provincial regulations. Examples included all electrical devices sold in Canada. In other cases, manufacturers or distributors prefer to have their products certified in compliance with CSA Standards for market acceptance, safety, quality or product design and evaluation considerations.

Some plumbing devices may be excluded from mandatory CSA compliance. Compliance is at the discretion of local or provincial plumbing authorities. This is the case with the Fiovalve where installation was permitted and actually encouraged by several provinces prior to CSA certification. Nevertheless CSA certification is beneficial to the consumer and Fiodrain Ltd. by ensuring compliance with national product and quality assurance standards. CSA certification is especially beneficial for achieving market acceptance, particularly with an innovative product.

2.1.2 Applicable CSA Standards

The Fiovalve backwater valve is subject to the National Standard of Canada specification CAN3-B181.1-M85 entitled “ABS Drain, Waste, and Vent Pipe and Fittings” published and administered by the Canadian Standards Association. It is classified as a “Type I” backwater valve intended for use in horizontal pipe runs.

This CSA standard covers three general areas:

- manufactured pipe and fitting requirements including dimensional and operational specifications;
- methods of testing for compliance; and
- product marking.

The majority of these requirements were previously satisfied and are not the subject of this investigation. These include materials specification with respect to hydrostatic pressure resistance, chemical resistance, water resistance and dimensional stability under load and temperature changes. Performance specifications include proper functioning of sealing elements, maximum flow restriction requirements, water tightness and minimum water flow rates.

Two very important amendments which improved the Fiovalve functionality were allowed to CAN B181.1-M85 under petition from Fiodrain Ltd; namely, the substitution of clear polycarbonate for the cover (the specification allows only ABS) and permitting the valve to be "normally open" (the specification requires "normally closed"). The clear cover allows visual inspection of the gate closure and its operation, and increases the strength of the cover. The normally open valve represents a considerable improvement over previous backwater valve operation as previously discussed.

CSA's certification is not limited to the product. The manufacturer and outside vendors, if applicable, are subject to a technical audit by CSA personnel. Manufacturing, quality assurance and documentation procedures must satisfy the CSA inspector in order to certify the fitting. Re-certification is required for vendor, material or manufacturing process substitution.

This investigation addressed certain dimensional tolerances and stability requirements, determined an acceptable manufacturing procedure, developed quality assurance procedures and documentation for Fiodrain's injection molding vendor and corrected product marking to successfully complete the CSA certification process.

2.1.3 Approval Procedures

Manufacturers must submit production samples to the appropriate CSA laboratory for compliance testing. The samples must represent actual production fittings, in this case using the injection molding vendor and the resin that will be employed for all future production. As noted, changes in material suppliers or injection molding vendors will require additional compliance testing of the fitting. Such testing is usually limited to dimensional and related checks but in some circumstances may require nearly complete re-certification.

Product specification compliance testing of the Fiovalve was conducted at the main CSA laboratories in Rexdale (Toronto), Ontario. All performance requirements had been satisfied and the two standard amendments (discussed in 2.1.2) were approved prior to the request by Fiodrain Ltd. for IHGP assistance. Unfortunately, CSA's Edmonton laboratory facilities were not equipped for Fiovalve testing requirements which necessitated all discussions with CSA testing personnel to be conducted by telephone or correspondence with the Toronto office. In addition to being time consuming, this led to some confusion on Fiodrain's behalf related to CSA's requirements and concerns. During the final compliance testing carried out in this investigation, a Fiodrain representative was present in Toronto. Direct discussions with the CSA certification staff greatly assisted Fiodrain Ltd. in providing CSA with the necessary quality assurance procedures.

In addition to the product testing, certification also requires a technical audit of the manufacturing process controls and quality assurance procedures. Generally, it is necessary to submit copies of the quality control manual for inclusion into the CSA certification file. CSA also conducts a review of the in-plant production quality assurance records to ensure quality assurance procedures are, in fact, being conducted on a continual basis.

CSA inspectors performed the audits on Fiodrain Ltd. and Columbia Plastics Ltd. of Vancouver (the injection molding vendor).

2.2 United States Certification

In the United States, building and other regulatory codes tend to be developed and administered by private and industry organizations. Hence national standards or, at least, the regulatory procedures, are less uniform than in Canada. Sometimes more than one organization may be involved in establishing and promoting standards such as those for plumbing fixtures.

Fiodrain Ltd is currently approaching two American organizations for possible certification. These are

- International Association of Plumbing and Mechanical Officials (IAPMO), 5032 Alhambra Avenue, Los Angeles, CA 90032-3490, and;
- Building Officials and Code Administrators (BOCA) International, 4051 West Flossmoor Road, Country Club Hills, IL 60477-5795

IAPMO recognizes CSA's Rexdale laboratories as an accredited testing facility for back-flow devices and will recognize their test results for U.S. certification. It is possible that BOCA will do likewise as a large number of testing laboratories have been accredited by BOCA. Reciprocal test report acknowledgements are common but not universal between Canada and the U.S.

At the time of writing, detailed test requirements have not been received from BOCA or IAPMO. However, they are expected to be similar, if not identical, to the CSA requirements as all have a common root in American National Standards Institute (ANSI) specifications.

3.0 IDENTIFICATION OF PROBLEMS

Problems identified during the inspection of the existing Fiovalve bodies and discussions with CSA, Fiodrain and injection molding vendor personnel are briefly described in this section. Solutions to these problems are presented in Section 4.0.

3.1 Manufacturing Problems

3.1.1 Injection Molded Body Dimensions

The major problem preventing CSA certification for the Fiovalve was dimensional. Both inlet and outlet spigot diameters were undersize as determined by the CSA Rexdale laboratory. Anderson Associates Consulting Engineers Inc.'s investigation indicated a second dimensional problem; namely, excessive out-of-roundness of the spigots. CSA had rejected the Fiovalve on simple diameter considerations and had not informed Fiodrain of the potentially more serious out-of-roundness problem. Out-of-roundness is generally more difficult to correct as it may be created by several factors acting singly or in concert. Factors affecting dimensional stability include shrinkage, resin variations, mold errors, injection molding and cooling parameters.

3.1.2 Injection Procedures

No records of the injection molding parameters existed. At the time of Anderson Associates Consulting Engineers Inc.'s involvement, two injection molders had provided two trial runs and one production run. Fiodrain Ltd. had not requested production records from the vendors and none were provided. Both vendors' main production products were food containers which required less strict dimensional tolerances. Hence it was necessary for Fiodrain to establish suitable injection molding process parameters and arrange for them to be adequately documented.

The Fiovalve castings are relatively complex and have strict tolerance limitations. Deviations from established injection procedures may result in product that must be scrapped. Hence, establishing appropriate engineering specifications as part of Fiodrain Ltd.'s purchase contracts was deemed essential.

3.1.3 Quality Assurance Procedures

Fiodrain Ltd. and the injection molding vendors had not developed any quality assurance procedures or documentation. CSA requires both the manufacturer and the injection molder to have a quality assurance procedure for each type of fitting produced and to maintain records documenting quality assurance testing.

Establishing quality assurance procedures and maintaining quality assurance (QA) records is good engineering and manufacturing practice. QA procedures, when properly implemented, will reduce a manufacturer's cost and enhance his product's reliability and reputation. This is accomplished by rejecting parts at the vendor's location (at his cost), rejecting out of specification components at an early stage before value is added, assisting cost recovery by identifying defective or substandard resins and preventing expensive recalls of defective products.

3.2 Product Enhancement

A review of the Fiovalve design and manufacturing procedures was conducted with Fiodrain Ltd. personnel. The consensus was that the Fiovalve was well designed functionally and that it operated reliably but that it was generally over designed structurally. Several items which could be addressed in the future were identified and are listed below:

- casting weight reduction;
- minor improvements to float chamber;
- improvements to the alarm system;
- assembly time reduction by an alternative lid fastener system, and;
- cost reductions to the lid seal.

A general discussion on these possible product or manufacturing efficiency enhancements is provided in Section 4.0.

4.0 SOLUTION OF PROBLEMS

4.1 Dimensional Problems

4.1.1 CSA Spigot Dimensional Requirements

Dimensions of fitting spigots are required by Paragraph 4.3.3.1 of CAN3-B181.1 to conform with “Table 1, Dimensions of Pipe” which is reproduced as Table I for 4 inch diameter schedule 40, ABS piping.

Table I: CSA Spigot Tolerance Requirements

Nominal pipe size, inches	Average outside Diameter, mm		Out-of-roundness, mm	Wall thickness, mm	
	Minimum	Maximum	Tolerance	Minimum	Maximum
4	114.30	114.68	±0.38	6.02	6.74

The out-of-roundness tolerances are specified as permissible deviations of actual diameters from the measured average diameter.

While Paragraph 4.3.3.1 specifies that male or spigot solvent weld ends on fittings shall conform to Table 1, an exception is that the minimum wall thickness shall be a minimum mean and a 10% variance on actual individual measurements shall be permitted.

Paragraph 5.3.2 defines the average outside diameter as the arithmetic mean of the maximum and minimum diameters at any cross-section. Sufficient measurements are to be made around the spigot to ascertain the maximum and minimum diameters have been determined. As an alternative, the average outside diameter may be determined from a measurement of the spigot circumference. (This latter method would still require determination of maximum and minimum diameter to calculate the out-of-roundness).

In summary, these tolerances are quite exacting. The maximum and minimum average diameters must fall within a 0.38 mm (0.015 inches) range while the maximum allowable total out-of-roundness is only 0.76 mm (0.030 inches) at any cross-section. The specification was established for conventional plumbing fittings which are highly symmetrical and relatively simple castings compared to the Fiovalve. A specification written around the Fiovalve style injection castings would have probably employed different dimensional tolerances.

4.1.2 Measurement of Original Spigot Diameters

Several Fiovalve body castings were obtained and measured to confirm CSA's contention that the spigot diameters were undersize. Typical results are presented in Table II. Samples 1 and 2 were injected by Pro-Western Plastics using the EDM modified molds and sample 3 was injected with the original mold at Columbia Plastics.

Table II: Typical diameters as measured at the very end of the spigots for the original castings.

Sample	Spigot	Maximum Diameter, mm	Minimum Diameter, mm	Average Diameter, mm	Out-of-Roundness, mm
1	Inlet	114.66	113.88	114.27	0.78
	Outlet	114.70	113.84	114.27	0.86
2	Inlet	114.70	113.88	114.29	0.82
	Outlet	114.70	114.06	114.38	0.64
3	Inlet	113.64	112.50	113.07	1.14
	Outlet	113.78	112.70	113.24	1.08

All spigots, except for the outlet of sample 2, failed for being undersize and exceeding the out-of-roundness tolerances. The orientation of the maximum and minimum diameters with respect to the body geometry was consistent for all samples as shown in Figure 5. The minimum and maximum diameters occurred at approximately right angles to one another. One might note that the modified spigots were only 0.01 to 0.03 mm (0.0008 to

0.0024 inches) undersize. CSA's measurements were about 0.20 mm undersize using a circumference tape. It is also probable that Samples 1 and 2, while out of dimensional specification, would have satisfactorily solvent welded to B181.1 fittings.

Visual examination of the bodies from the modified mold indicated an abrupt mold parting line on both spigots. Diameters measured adjacent to each side of the parting line varied by about 0.25 mm.

Average diameters measured 10 mm or more away from the end of the spigot and were 0.20 to 0.30 mm undersize. CSA had measured average diameters in these locations which were even less using a circumference tape. One might note that, in the writer's opinion, the use of the circumference or "Pi" tape does not follow the definition of average diameter; individual diameter measurements represent the referenced method.

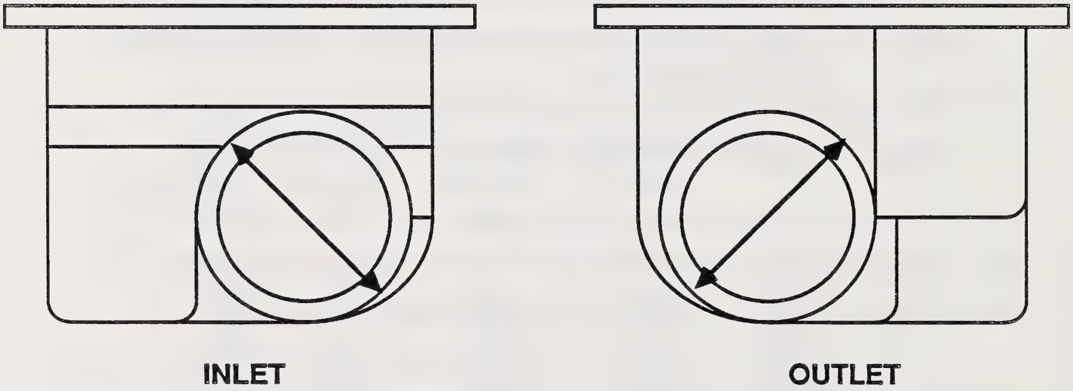


Figure 5: Residual stresses due to the differential cooling and asymmetric body geometry distort the spigots out-of-round. The minimum diameter shown by the arrows occurs where the body stiffens the spigots the least. The maximum diameter occurs at right angles to the arrows which represents the direction of greatest stiffness.

4.1.3 Determination of Shrinkage

Common locations on the mold and injected parts were measured in order to determine the material shrinkage factor. Areas measured were across the gasket flats which were determined to be free of distortion. Linear shrinkage in the original bodies supplied by Columbia was 0.54% (0.005 mm/mm) and was 0.67% (0.007 mm/mm) for those injected by Pro-Western. These are mid range values for injection molded ABS resins which suggested that abnormal shrinkage characteristics were not the major contributor to the dimensional problems. The differences in shrinkage between the two vendors are an indication of the effects of differing injection parameters.

4.1.4 Inspection of the Fiovalve Body Mold

The complicated geometry required for the Fiovalve body's design has created a complex and massive 3500 kg mold. The movable platen contains the male core of the body while the fixed platen contains the female image. Movable core blocks are required on both ends because of the spigots and end flanges. As the movable platen closes, the end cores located in the fixed platen must first close in the same direction as the movable platen. Then the core blocks must slide inward towards the centre simultaneously closing the mold cavity as the movable platen closes. All of this results in a complex, very costly injection molding die.

The upper half diameters of the spigots are formed from the movable end core blocks while the lower half diameter are formed from the fixed platen female cavity. A complicating factor arises in that the ends of the fixed platen and the end core blocks are closed thus precluding simple diameter modifications by boring with the dies assembled. Half diameters in the fixed platen cavity are best sunk or modified using electronic discharge machining (EDM). This involves creation of a male EDM electrode of copper or graphite with copper preferred for exacting work. An electrical discharge (spark) erodes the die to the shape and dimensions of the electrode in a dielectric fluid. On the other hand, the half diameter in the core block may be milled using a horizontal milling machine once the mold is disassembled.

Assembling one core block into the fixed platen and closing the mold allowed measurement of the horizontal and vertical spigot diameters in the mold. These were as shown in Table III:

Table III: Mold spigot diameters prior to final correction by machining.

	Inlet diameter, mm	Outlet diameter, mm
Vertical	115.14	115.21
Horizontal	115.32	115.32

The vertical half diameter of the spigots in the fixed platen cavity was exactly one half of the horizontal diameter. This indicated the difference between horizontal and vertical diameters of 0.18 and 0.11 mm for the inlet and outlet spigots respectively were due to an error in the end core blocks. Additionally the longitudinal centre lines of the spigots core block were not exactly coincident with the longitudinal spigot centrelines of the female cavity in the fixed platen. These were shifted laterally 0.08 mm.

4.1.5 Analysis and Correction of Mold Problems

An analysis of the body casting measurements indicated that two deficiencies required correction; namely, undersize spigot outside diameters and excessive out-of-roundness. Reviewing the mold dimensions, it became apparent that two factors were contributing to the dimensional deficiencies. These were mold inaccuracies and distortion of the body during cooling.

Considering the mold first, the end core blocks which form the upper half of the spigots were not true half circles as required and the centrelines were slightly non-coincident. Since the core blocks could be removed from the main mold, correction of these deficiencies could be performed in a milling machine with a boring bar or fly cutter. The lower half spigot die in the main die block (fixed platen) was geometrically correct.

Due to thermal shrinkage, the female spigot mold must have a slightly larger diameter. Shrinkage depends on other variables than the thermal expansion coefficient and includes such factors as specific ABS composition, injection pressures, holding times, temperatures and cure times. A slight variation in the linear shrinkages existed for the two Fiovalve manufacturers of about 0.15% (0.0015 mm/mm). Since these were mid range of published literature values, the decision to correct the spigot end core dimensions to match the main die block was taken. A major concern was not to make the spigots oversize since this would cause major die repair costs. Previous maximum diameters were exceeding the maximum allowable average diameters. Hence the approach was prudent and, if the spigots were still undersize due to linear shrinkage, the molds could be further enlarged.

The consistent orientation of the maximum and minimum diameters and the degree of out-of-roundness of the parts compared to the mold cavity measurements provided evidence that distortion was occurring during the cooling cycle.

As Figure 5 on page 15 illustrates, the major spigot axis occurs in the direction where the rectangular body geometry assists the spigot stiffness to the greatest extent. Similarly, the minimum spigot diameter occurs in the direction where the body geometry would have the least stiffening effect. Thermally induced stresses develop, in part, when differential cooling rates exist due to body geometry. As the temperature decreases, contraction occurs. If the part was symmetrical and cooled uniformly, no stresses would develop. However, differential cooling develops differential contraction which creates stresses. This problem is created since the resistance to stress changes with the material temperature, that is, the plastic's strength depends on temperature. Hence, for example, when an area which cools later begins to contract it may find itself restrained by cooler (and stiffer) material. This constraint may cause a high stress to be developed. One can see that part geometry also affects the development of residual stresses in a similar manner by creating areas of variable stiffness or resistance to shrinkage forces.

Residual stresses can have a large magnitude, approaching or exceeding the yield point which results in distortion of the component. Designing molds to accommodate or prevent such distortions presents a major challenge to the die engineer. The Fiovalve body shape, while quite functional, is very susceptible to such shape dependent distortion.

Since the die alterations would be very costly, it was decided to try to resolve the thermally induced residual stress distortion during production trials with the existing mold. Trials would involve varying the injection parameters in a known manner and observing the results on the spigot dimensions. If these trials indicated the tolerance requirements could not be accomplished by varying process parameters, then the main die block would have to be re-machined to provide more symmetrical stiffness at the spigot-to-body connection.

The inlet and outlet core blocks were machined to match the half diameters in the fixed platen at Szantech Machine Tools Inc. After reassembly, the inlet and outlet bores were measured at 115.32 ± 0.03 mm in diameter or essentially within the tolerance limits of the repair method employed.

4.1.6 Empirical Injection Molding Trials

Injection trials were performed at Columbia Plastics Ltd's Surrey, B.C. plant to empirically determine what injection parameters, if any, would create dimensionally acceptable castings.

The castings were produced on a Kawaguchi reciprocating screw injection molding machine with the following specifications:

- clamping force, 600 Tonnes (660 tons)
- maximum injection pressure, 138 MPa (20,000 psi)

- injection volume, 2.73 L (166.77 in^3)

Measurement and temperature control of the plastic occurred at six locations along the screw.

Table IV: Summary of injection parameter trials conducted at Columbia Plastics Ltd.

Trial	Injection Pressure, psig	Injection Temperature at Nozzle, °F	Injection Pressure Hold Time, Seconds	Cure Time Seconds	Total Injection Cycle Time, Seconds	Comments
1	5000	435	30	90	175	
2	6000 - 9000	435	30	80	165	
3	8000	435	30	70	155	
4	8000	435	30	60	145	
5	8000	435	30	50	125	
water tests	8000	465	30	50	125	quench in cold water - also trials with complete cooling in mold
6	5000	465	30	50	118	
7	5000	450	24	50	112	
8	5000	450	40	50	128	
9a	5000	430	30	50	118	120°F water to all molds except cold water 40°F to end cores
9b	5000	430	50	50	138	"
10	5000	450	50	50	138	"

The injection material was Borg Warner Cycolac GSM-4106, a high impact, injection molding ABS grade, which will be used in all future production runs.

The empirical trials involved injecting several valve bodies under varying injection parameters and measuring both inlet and outlet spigots to determine minimum and maximum diameters. This established the trend of the average diameters and especially the out-of-roundness. A series of 13 trials with different injection parameters were performed as shown in Table IV. Generally the parameters were held constant during each trial, although in some cases a particular parameter might be varied. One hundred and ten samples were measured and recorded. Measurements were also repeated over time to determine any time-dependent effects.

The injection parameters studied were as follows:

• injection pressure	the injection pressure applied to the plastic by injection machine screw. Higher injection pressures tend to pack the cavity reducing subsequent shrinkage.
• injection time	the time that the injection pressure is held. This represents the time available for additional material to enter the cavity. It also affects the residual stresses as the material in the die is cooling while under pressure.
• cure time	the time the part is left in the mold to cool with the mold clamping force applied but the injection pressure removed. The die blocks are water cooled and it is possible to vary flow rates and temperatures to alter the cooling pattern in the part.

• cycle time	total injection cycle time to close the die, inject the plastic, cure in the mold, open die and eject part. Cycle time determines the variable cost portion of the injected part.
• cooling water	the temperature and flow rate affect the die's temperature hence the heat transfer rates from the part.
• injection temperature	the temperature of the plastic at the injection nozzle. Injection temperature affects die filling, cooling rates and shrinkage. Excessive temperatures may lead to burning while inadequate temperatures may lead to underfilling of the die.
• quenching	involves quickly cooling the ejected part in cold water to "freeze" the plastic to prevent stresses from already cooled material from distorting softer, warmer material or alternatively to attempt to produce a more uniform cooling rate to prevent residual stresses whose magnitudes are location sensitive.

Early results indicated that injection pressure affected the average diameter with greater pressures increasing the average diameter. Measured immediately after molding, the spigots from a wide range of injection parameters were found to be acceptable with respect to average diameters and out-of-roundness. As expected, average diameters decreased due to thermal contraction upon cooling. However, in most instances the average diameters were acceptable.

Out-of-roundness measured immediately after injection was minimal at 0.05 to 0.25 mm compared to the 0.76 mm allowable. However, out-of-roundness was extremely time dependent and increased drastically as the body cooled. Out-of-roundness could reach 1.25 mm under certain conditions. In some cases, acceptable spigots when measured an hour after injection were satisfactory but were later rejected due to excessive out-of-roundness tolerance when measured several hours later or the next day. This confirms the large magnitude of the residual stresses since the distortion occurred after the parts had essentially attained a common temperature and strength. In these cases, the distortion represented creep under a high stress loading.

Empirically, longer injection times with higher injection temperatures were found to produce castings that become stable after about 1 1/2 hours. Figure 6 shows the time-dependent distortion as indicated by out-of-roundness for a sample injected in trial 10 which remained stable when measured 16 hours later.

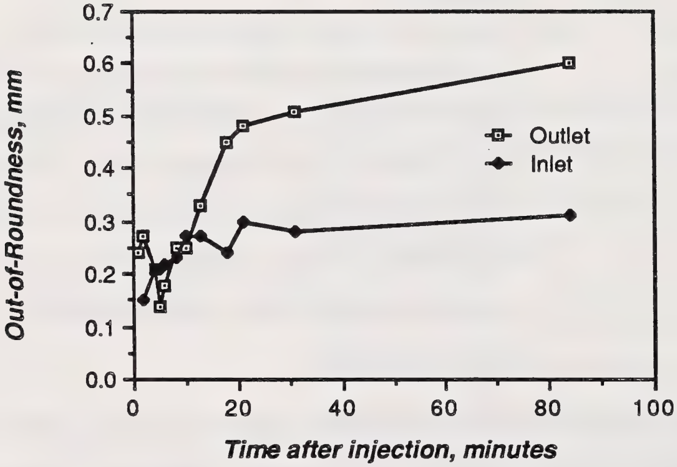


Figure 6: Typical distortion of the spigots (measured at the extreme ends) as a function of time after injection.

Since residual stresses which developed during cooling appeared responsible for the distortion, attempts were made to modify the mold's heat transfer pattern by introducing warm water to certain portions of the mold. The water cooling passages in the mold allow a large number of water flow combinations. However, simply separating the female core block from the end and the male core blocks provided satisfactory results. Warm 120°F cooling water was fed to the female (fixed platen) die block.. Cooling water at 40°F (water main ambient) was fed to the body and end core blocks. This has the effect of increasing the cooling rate of the body relative to the spigots while in the mold. Hence less thermal contraction should occur after ejection and stresses should be lower. This appears to be born out in practice.

Injection parameters of trial 10 gave satisfactory results and were used for the first production run of CSA dimensionally certifiable bodies. Table AI, reproduced in the appendix, gives both spigots' average diameters and out-of-roundness for the first 31 production samples produced at Columbia. Columbia personnel were instructed on the interim quality assurance procedures. In the initial production run of over 500 units, all body castings were satisfactory dimensionally (and in all other respects).

As Table AI indicates, average diameters are mid range at 114.51 and 114.41 mm for the inlet and outlet respectively with standard deviations of ±0.02 mm (0.001 inches). Out-of-roundness tends to the high side of the 0.76 mm allowable at 0.61 ± 0.05 and 0.68 ± 0.04 mm for inlet and outlet respectively. Again the standard deviations are small indicating the process provides consistent results. The production run met all CSA dimensional requirements.

4.2 Correction of Labelling Problems

CSA certification personnel requested several labelling changes to comply with CAN 3-B181.1-M85 and CSA's monogram practice. These were:

- elimination of a non-standard CSA mark on the body
- elimination of the word "sewer" on the body identification marks
- addition of a CSA monogram on the lid so as to be visible once the Fiovalve is installed

These simple mold modifications were performed as requested. As an interim measure to allow use of the existing lids, a pressure-sensitive adhesive label was used. The cover mold has since been engraved with the CSA monogram.

4.3 Quality Assurance of the Body Injection Moldings

Quality assurance (QA) procedures are unfortunately frequently believed to be only in the domain of large, technically staffed organizations. While this might once have been true, standardization organizations such as CSA and the increasing incidence of product litigation have made quality assurance mandatory at all manufacturing levels.

The Fiovalve is an engineered product which is subject to strict engineering specifications and legal interpretation of those specifications. Thus minor dimensional inaccuracies may require rejection of product that is otherwise entirely functional. Hence it is important to include engineering specifications and QA requirements with all purchase contracts and to establish in-house QA on all incoming castings.

Fiodrain Ltd's management is cognizant of the need for quality assurance on the Fiovalve castings and have established the following procedures.

4.3.1 Quality assurance requirements at Columbia Plastics Ltd.

As a result of this investigation, an engineering specification is part of each purchase contract. This document, reproduced in the appendix, specifies the material, dimensional requirements, quality assurance procedures, acceptance criteria and documentation requirements. It also permits materials traceability of each resin batch lot number. A quality assurance report form (see appendix) is provided which Columbia Plastics must complete for Fiodrain's and CSA's records.

4.3.2 Quality assurance requirements at Fiodrain Ltd.

All incoming castings are visually inspected. One out of ten body injections received is measured for the critical spigot dimensions which are recorded on a QA report form. A copy of this form is presented in the appendix. The quality assurance records from Columbia and Fiodrain are related by lot numbers and are maintained for future reference and perusal by CSA inspectors.

4.4 Assembly Quality Assurance

Fiodrain Ltd. has developed an in-house QA program during assembly. This includes visual inspection of all components and testing for proper operation of all Fiovalves and alarms. In addition, 1 percent of all Fiovalves are subjected to the water tightness test required by CAN3-B181.1. These Quality Assurance procedures also form part of the CSA compliance program.

4.5 Product Enhancement

4.5.1 Body Casting

The present body casting is entirely adequate and satisfactory. However, it is over-designed and could function equally well with redesign to reduce casting weight. Weight savings of 30 to 40 per cent are possible. These alterations are known to Fiodrain Ltd. and may be applied in the future as cost reduction techniques when the current mold costs are amortized. Currently market competitive forces do not require such material reduction economies.

4.5.2 Float Chamber

A minor improvement to the float has been made consisting of a raised rib to prevent possible sticking of the float. While this has not been a problem, float sticking could exist during minor back-ups in certain cases.

Stagnant drains will allow a low fluid level to exist in the Fiovalve. Under conditions of high grease loadings, collection of solidified fats is possible in the float chamber causing float sticking unless turbulent conditions exist during the backflow. While such conditions represent drain malfunctioning, this simple modification will improve the Fiovalve operation in any event.

4.5.3 Improvements to the Alarm System

An improved electrical connection technique has been recommended and will be used. Currently connections are protected with shrink-fit tubing. Under some wet conditions with high salt contents shorting may occur. An improved shrink-fit connection containing a corrosion inhibited, thermoplastic, encapsulating material developed for the aerospace industry will be substituted.

Encapsulation of the magnetic switch is also being performed to prevent mechanical damage during installation and service degradation under wet, high conductivity situations.

4.5.4 Assembly cost reductions.

With the present molds, a major cost reduction could be achieved with minimal mold modification costs by switching to self tapping threaded fasteners instead of the present nut and bolts. Cost savings would come by reduced labour costs of installation, and reduced materials costs. The number of fasteners could also be reduced from the present fourteen.

4.5.5 Cost reductions of the lid seal.

Replacement of the current die-cut lid gasket with a molded gasket is not economically feasible at current production rates. Slight redesign of the lid/body flange could allow utilization of off-the-shelf gasketing (O-rings). Alternatively cast-in-place gaskets are possible. Both alternatives, which require mold modifications, are currently under consideration.

5.0 CERTIFICATION

5.1 Canadian Standards Association

The Fiovalve has received CSA certification under report LM61387-2 dated June 18, 1987.

Representatives of Fiodrain Ltd. and Anderson Associates Consulting Engineers Inc. were present at the final certification testing in Toronto. In addition to witnessing the dimensional measurements, the quality assurance procedures and criteria developed were presented to CSA regulatory personnel. This greatly facilitated CSA's acceptance of the procedures and recommendations developed during the course of this project.

5.2 American Certification

At the time of writing, preliminary correspondence with BOCA and IAPMO officials was underway in order to achieve certification under those regulatory bodies. In at least the IAPMO case, CSA is a recognized testing laboratory whose results are acknowledged and accepted in lieu of additional tests. U. S. certification appears to present no additional problems and may be obtained when entry into the American market is desired.

6.0 CONCLUSIONS

This IHGP supported investigation has determined that the Fiovalve, as designed, manufactured and sold, is in compliance with the applicable Canadian Standards Association Standard CAN3-B181.1. No modifications to the design or function were necessary for the Fiovalve to meet and exceed all performance requirements. Original difficulties in obtaining CSA certification were entirely dimensional in nature and were related to subtleties in mold dimensions and processing parameters.

Minor mold modifications and extensive injection molding trials have established manufacturing procedures which produce dimensionally accurate costings within the narrow tolerance limits allowable. Suitable engineering purchasing specifications and quality assurance procedures at the injection molding and assembly levels have been established and implemented in order to obtain CSA certification and ensure continued compliance.

Fiodrain Ltd's management are fully committed to maintaining the level of quality control developed during this investigation. The necessary quality assurance inspection and measurement equipment has been purchased and installed. Responsibility for quality assurance procedures and documentation maintenance has been established.

Implementation of the above procedures are cost effective and will reduce production costs through lower rejection rates. Areas of product improvement and further cost reduction have been identified and Fiodrain management is in a position to introduce them as necessitated or permitted by market forces.

The objectives of this project have been achieved and, as a result, Fiodrain Ltd. is better able to efficiently produce Fiovalves and market them successfully.

APPENDIX

1. List of abbreviations used in report. A-1
2. Table AI. Summary of dimensional accuracies attained during initial production run of Fiovalve body castings. A-2
3. Fiodrain Ltd. Specification for Injection Molded Fiovalve Body Castings. A-3
4. Fiodrain Ltd. - Receiving Inspection Report for Fiovalve Body Castings. A-6
5. Columbia Plastics Ltd., Fiovalve Body Casting Spigot Diameter Quality Assurance Report. A-7

LIST OF ABBREVIATIONS

ABS	Acrylonitrile - Butadiene - Styrene
ANSI	American National Standards Institute
BOCA	Building Officials and Code Administrators International
CSA	Canadian Standards Association
EDM	Electrical (spark) discharge machining
IAPMO	International Association of Plumbing and Mechanical Officials
IHGP	Innovative Housing Grants Program, administered by the Research and Development Section, Housing Division, Alberta Municipal Affairs
QA	Quality assurance

Time Sample Injected	Time Sample Measured	Total Cooling Time, minutes	Minimum Outlet Diameter, mm	Maximum Outlet Diameter,mm	Average Outlet Diameter, mm	Out-of-Round Outlet mm	Minimum Inlet Minimum, mm	Maximum Inlet Maximum, mm	Average Inlet Diameter, mm	Out-of-Round Inlet mm
840	1005	85	114.09	114.81	114.45	0.72	114.31	114.82	114.57	0.51
842	1011	89	114.10	114.82	114.46	0.72	114.23	114.83	114.53	0.60
845	1017	92	114.14	114.80	114.47	0.66	114.25	114.84	114.55	0.59
847	1020	93	114.12	114.75	114.44	0.63	114.25	114.83	114.54	0.58
849	1021	92	114.09	114.83	114.46	0.74	114.30	114.74	114.52	0.44
851	1022	91	114.10	114.76	114.43	0.66	114.23	114.80	114.52	0.57
853	1023	90	114.08	114.72	114.40	0.64	114.15	114.80	114.48	0.65
855	1024	89	114.08	114.72	114.40	0.64	114.20	114.83	114.52	0.63
858	1025	87	114.08	114.71	114.40	0.63	114.20	114.82	114.51	0.62
900	1028	88	114.09	114.71	114.40	0.62	114.21	114.81	114.51	0.60
903	1029	86	114.05	114.72	114.39	0.67	114.21	114.81	114.51	0.60
905	1030	85	114.06	114.74	114.40	0.68	114.22	114.82	114.52	0.60
907	1032	85	114.06	114.78	114.42	0.72	114.16	114.91	114.54	0.75
910	1042	92	114.07	114.75	114.41	0.68	114.20	114.86	114.53	0.66
913	1043	90	114.06	114.76	114.41	0.70	114.23	114.84	114.54	0.61
915	1045	90	114.06	114.73	114.40	0.67	114.17	114.81	114.49	0.64
918	1046	88	114.08	114.73	114.41	0.65	114.18	114.82	114.50	0.64
920	1048	88	114.05	114.73	114.39	0.68	114.18	114.82	114.50	0.64
922	1050	88	114.10	114.72	114.41	0.62	114.19	114.86	114.53	0.67
925	1051	86	114.08	114.73	114.41	0.65	114.18	114.84	114.51	0.66
927	1052	85	114.04	114.71	114.38	0.67	114.21	114.82	114.52	0.61
930	1053	83	114.06	114.70	114.38	0.64	114.17	114.82	114.50	0.65
933	1055	82	114.02	114.73	114.38	0.71	114.15	114.82	114.49	0.67
935	1056	81	114.04	114.76	114.40	0.72	114.21	114.80	114.51	0.59
937	1058	81	114.04	114.76	114.40	0.72	114.21	114.80	114.51	0.59
939	1059	80	114.04	114.76	114.40	0.72	114.21	114.80	114.51	0.59
941	1100	79	114.04	114.76	114.40	0.72	114.21	114.80	114.51	0.59
943	1102	79	114.04	114.76	114.40	0.72	114.21	114.80	114.51	0.59
945	1104	79	114.04	114.76	114.40	0.72	114.21	114.80	114.51	0.59
947	1106	79	114.04	114.76	114.40	0.72	114.21	114.80	114.51	0.59
950	1108	78	114.04	114.76	114.40	0.72	114.21	114.80	114.51	0.59
Number	31	Mean	114.07	114.75	114.41	0.68	114.21	114.82	114.51	0.61
		Std Deviation	0.03	0.03	0.02	0.04	0.04	0.03	0.02	0.05
		Maximum	114.14	114.83	114.47	0.74	114.31	114.91	114.57	0.75
		Minimum	114.02	114.70	114.38	0.62	114.15	114.74	114.48	0.44

Table AI: Summary of dimensional accuracies attained during initial production run of Fiovalve bodies at Columbia Plastics Ltd.

Fiodrain Ltd. Specification for Injection Molded Fiovalve Body Castings

1.0 Material

1.1 The material of manufacture is to be Borg-Warner "Cycolac" GSM-4106 ABS thermoplastic. The lot or batch numbers are to be recorded on the quality assurance report supplied.

1.2 Material substitution will require additional CSA Certification tests. Do not substitute another grade or another manufacturer's product without written permission from Fiodrain Ltd.

2.0 Quality assurance procedures

2.1 One sample every half hour beginning with the first acceptable quality casting shall have the maximum and minimum outside diameters of the spigots measured and recorded on the "Fiovalve Body Casting Spigot Diameter Quality Assurance Report". The diameter is measured at the end of the spigot.

2.2 An elapsed time of 90 minutes (1 1/2 hours) minimum from the time of injection to the time of measurement is required for the casting to stabilize dimensionally.

2.3 The average outside diameter defined as the sum of the maximum and minimum outside diameters divided by two shall be calculated and recorded on the quality assurance report. Also the out-of-roundness shall be calculated as the difference between the maximum and minimum outside diameters and recorded.

2.4 The acceptance criteria is:

- Allowable average diameter range is 114.30 to 114.68 mm inclusive (4.500 to 4.515 inches)
- Allowable out-of-roundness is equal to or less than 0.76mm (0.030 inches)

2.5 The measured body castings shall be numbered as per the quality assurance record report by suitable means. Tape or stickers are acceptable.

2.6 The quality assurance report shall record the vendor's lot number, purchase order reference and the total number of pieces injected.

2.7 The completed quality assurance report shall be signed by the inspector on behalf of Columbia Plastics Ltd.

2.8 A copy of the completed quality assurance report shall be kept by Columbia Plastics Ltd. to satisfy CSA requirements.

2.9 A copy of the completed quality assurance report shall be forwarded for Fiodrain Ltd. records.

3.0 Rejection

3.1 All body castings failing to meet the criteria of 2.4 are rejected.

3.2 If rejection for dimensional criteria occurs, a sufficient number of additional castings shall be measured to ensure dimensional compliance.

3.3 Rejected castings may be ground and recycled with virgin material in appropriate proportions.

4.0 General

4.1 The injection cycle parameters are at Columbia Plastics Ltd's discretion provided the dimensional criteria of 2.4 are satisfied.

4.2 The following parameters have been found to provide satisfactory castings previously and may be used as general guidelines:

- injection pressure, 5000 psi
- injection time, 50 seconds
- cure time, 50 seconds
- Cooling - cold water to body core and inlet cores
  - warm (120°F) water to remainder of mold
- melt temperature 450°F at nozzle
- cycle time 2 minutes 18 seconds

FIODRAIN LTD. - RECEIVING INSPECTION REPORT

: Fiovalve Body Casting P.O. Reference No. :____________________ Page___ of ___

rain lot number:__________ Total number of pieces:_________ Date received:___________

dor:____________________________________ Vendor's lot number:____________

ection date:___________ Inspector:____

SAMPLE		Spigot Diameter			Reject	Out of Round	Reject	Wall Thickness		Injection Quality
		Max.	Min.	Avg.				Max.	Min.	
	Outlet									
	Inlet									
	Outlet									
	Inlet									
	Outlet									
	Inlet									
	Outlet									
	Inlet									
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	Outlet									
	Inlet									
	Outlet									
	Inlet									

$$\text{Average diameter} = \frac{\text{Maximum diameter} + \text{Minimum diameter}}{2}$$

Allowable range is 114.30 to 114.68 mm (4.500 to 4.515 inches)

Out of roundness = Maximum diameter -Minimum diameter

Allowable is less than or equal to 0.76 mm (0.030 inches)

Wall thickness Allowable range is 6.02 to 6.74 mm (0.237 to 0.265 inches)

COLUMBIA PLASTICS LTD. P.O. #______________

Fiovalve Body Casting Spigot Diameter Quality Assurance Report

Vendor's lot number:__________ Total number of pieces:________ Page___ of ___

Date:____________________ Inspector (Printed):____________________

Cycolac lot number:__________ Inspector (Signed):____________________

Body No.	Time Sample Injected	Time Sample Measured	Inlet Spigot Diameter			Out of Round	Outlet Spigot Diameter			Out of Round
			Max.	Min.	Avg.		Max.	Min.	Avg.	

$$\text{Average diameter} = \frac{\text{Maximum diameter} + \text{Minimum diameter}}{2}$$

Allowable range is 114.30 to 114.68 mm (4.500 to 4.515 inches)

Out of roundness = Maximum diameter -Minimum diameter

Allowable is less than or equal to 0.76 mm (0.030 inches)

Wall thickness Allowable range is 6.02 to 6.74 mm (0.237 to 0.265 inches)

IMPORTANT: A minimum of 90 minutes between part injection and spigot measurement is required as the spigot diameters are unstable during this time.

Metric units take precedence over English units.

N.L.C. - B.N.C.
3 3286 09859978 6